

5/PRTS

INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE

Background Information

5 The present invention relates to an interferometric measuring device for measuring the shape especially of rough surfaces of a measured object, having a radiation-producing unit emitting short-coherent radiation, a beam splitter for forming a first and a second beam component, of which the first is directed via an object light path to the measured object and the second is directed via a reference light path to a reflective
10 reference plane, having a superposition element at which the radiation coming from the measured object and the reference plane are brought to superposition, and an image converter which receives the superposed radiation and sends corresponding signals to a device for evaluation, the optical
15 path length of the object light path being changed relative to the optical path length of the reference light path.

Such an interferometric measuring device is known from German DE 197 21 842 C2. In the case of this known measuring device,
20 a radiation-producing unit, such as a light-emitting diode or a superluminescent diode, emits a short-coherent radiation, which is split via a beam splitter into a first beam component guided over an object light path, and a second beam component guided over a reference light path. The reference light path
25 is periodically changed, using two deflector elements and a stationary diffraction grating positioned behind it, by activating the deflector elements, so as to scan the object surface in the depth direction. If the object light path and the reference light path coincide, a maximum interference

contrast results, which is detected using an evaluation device post-connected to the photodetector device.

An interferometric measuring device representative of the measuring principle (white-light interferometry or short-coherent interferometry) is also specified in German DE 41 08 944 A1. Here, however, a moved mirror is used to change the light path in the reference ray path. In this method, the surface of the object is imaged on the photodetector device, using an optical system, it being difficult, however, to conduct measurements in cavities.

Additional such interferometric measuring devices and interferometric measuring methods based on white-light interferometry are described by P. de Groot, L. Deck, "Surface Profiling by Analysis of white-Light Interferograms in the Spatial Frequency Domain" J. Mod. Opt., Vol. 42, No. 2, 389-401, 1995 and No. T. Maack, G. Notni, W. Schreiber, W.-D. Prenzel, "Endoskopisches 3-D-Formmesssystem", (Endoscopic 3-D Shape Measuring System) in Jahrbuch für Optik und Feinmechanik, Ed. W.-D. Prenzel, Verlag (publisher) Schiele und Schoen, Berlin, 231-240, 1998 verwiesen (submitted).

In the case of the interferometric measuring devices and measuring methods named, one difficulty is making measurements in deep cavities or narrow ducts. One suggestion for a measuring device in which measurements can be performed even in cavities, using white-light interferometry, is shown in German DE 197 21 843 C1. It is proposed there to split a first beam component further into a reference beam component and at least one measuring beam component, an additional beam splitter and the reference mirror being positioned in a common measuring probe. To be sure, such a measuring probe can be introduced into cavities, however, using this device, in each measurement, only a small, dot-like location in the surface can be scanned. In order to take the measure of more locations on the surface in the depth direction, relative motion between

measured object and measuring probe is required, an exact lateral coordination, however, being costly and difficult.

The object of the present invention is to make available an interferometric measuring device, of the kind mentioned at the outset, which especially makes possible simplified measurements in deep cavities with great accuracy.

This object is achieved by the features of Claim 1. According to this it is provided that an optical probe in the object light path, having an optical device for generating at least one optical intermediate image, be provided.

Similarly to an endoscope or a borescope, in using the optical device, because of the intermediate images, it becomes possible to image the observed surface, besides using high longitudinal resolution, also at high lateral resolution over a path which is long compared to the diameter of the imaging optics. For example, the optical probe can be introduced into the bores of valve seats or into vessels of organisms for the purpose of medical measurements. In contrast to the usual endoscope, quantitative depth information is now obtained. In this connection, an advantageous embodiment is one in which the at least one intermediate image is generated in the object light path. For this, the same optical device is used for illuminating the measured location on the measured object as for transmitting the radiation coming from the measured object to the photodetector device, if it is provided that both the radiation going to the measured object and the radiation coming back from it pass through the optical probe.

The optical image on the photodetector device can be improved by providing, in the reference light path, an equal, further optical probe or at least a glass device for compensating for a glass proportion present in the optical probe with regard to the elements for the intermediate image(s).

5
10
15
20

25

30

35

Figure 2 a second exemplary embodiment in which an optical

•

5

10

15

35

5 component. A high interference contrast occurs in the image of
measured object O when the path difference in the reference
light path and the measured light path is less than the
coherence length. With regard to this, the measuring principle
10 is based on white-light interferometry (short-coherent
interferometry), as is described in greater detail in the
documents mentioned at the outset. The length of the reference
light path is varied over the entire measuring range for
scanning in the depth direction of the surface to be measured,
the length of the reference light path being detected for each
15 measured point at which the greatest interference contrast
appears. It is made possible by the intermediate images to
image the surface of the measured object at a high lateral
resolution over a range that is large compared to the diameter
of the imaging optics. Optical probe OSO resembles an
20 endoscope and a borescope, however, the illumination and the
feedback of the radiation coming from the measured surface via
the same optical device occurring via at least one
intermediate image. Figure 1 shows schematically some lenses
L as further imaging elements. The actual intermediate images
25 are created in optical probe OSO.

For applications, in which an exact compensation for the influence of the imaging lenses of optical probe OSO is required, the same optical probe OSR is also integrated in the reference light path or reference arm between beam splitter ST1 and reference mirror RSP as in the object light path between beam splitter ST1 and measuring object O, as shown in Figure 2.

35 In a modified design according to Figure 3, the
interferometric measuring device may also be realized as a
device having common reference and measuring arms (common path

5

10

20

25

30

35

assembly, so that aberrations are substantially compensated for. Moreover, this set-up is more rugged and, therefore, less susceptible to mechanical shocks.

5 For even simpler handling of the measuring device, the radiation of beam splitter ST1 can also be transmitted to further beam splitter ST1, using fiber optics LF, as is shown in Figure 4.

10 A further alternative design is shown in Figure 5. As an
alternative to the design having the common reference path and
measuring light path as in Figures 3 and 4, a combined
Mach-Zehnder-Michelson arrangement is provided. Again, a
broadband radiation-producing unit SLD is used, whose
15 radiation is coupled into a fiber optic element. First beam
splitter ST1 splits the radiation into an object arm OA and a
reference arm RA. In object arm OA, first beam component T1 is
coupled out of the corresponding light conducting fiber and
coupled into optical probe OSO via further beam splitter ST2,
20 so that the surface to be measured of measured object O is
illuminated. The object surface is imaged by optical probe OSO
via one or more intermediate images on image sensor BS. In
reference arm RA light is coupled out of the corresponding
light-conducting fiber, is then propagated, if necessary,
25 through the same optical probe OSR as is applied in object arm
OA, and is coupled in by a second fiber coupler R2 to a
light-conducting fiber positioned there. The reference wave
reaches further beam splitter ST2 via the light-conducting
fiber. There it is uncoupled and superposed with the object
30 wave on image sensor BS via further beam splitter ST2. In both
arms, the optical paths in the air, in optical probes OSO or
OSR as well as in the light-conducting fibers have to be
adjusted. Tuning of the path lengths in reference arm RA is
performed here, for example, by shifting second fiber coupler
35 R2, so that the optical air path in the reference arm is
changed.